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ABSTRACT

Included in this science activities energy package are 12 activities related to wind energy for elementary students. Each activity is outlined on a single card and is introduced by a question. Topics include: (1) At what time of day is there enough wind to make electricity where you live?; (2) Where is the windiest spot on your schoolground?; and (3) How much wind is needed to turn a modern wind machine? Most of the activities in the series can be completed in the classroom with materials readily available in any community. (BB)

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Science Activities In Energy

Wind Energy

DOE IR 0037

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SCIENCE ACTIVITIES IN ENERGY

Science Activities in Energy is a series of simple, concrete, revealing experiments that was developed by the American Museum of Science & Energy especially for fourth, fifth, and sixth graders but can be just as useful in community programs.

The purpose of the series is to illustrate certain principles and problems related to various forms of energy and to their development, use, and conservation.

More important, it is an effort to help you and other teachers involve students directly in exploring intriguing questions—in making discoveries on their own.

You needn't be an expert in science to use this material. In fact, teachers shouldn't be expected to know the "right" answer to every question posed. What's more, many of the activities involve not just science but art, economics, arithmetic, reading, and other skills and disciplines as well—and need not be used in sequence.

Each unit in the series forms a coherent program of instruction on a single topic: electrical energy, conservation, chemical energy, and solar energy for both elementary and secondary levels.

Most activities in the series can be completed in the classroom with materials readily available in any community: pots and pans, paper cups, water, salt, thermometers, and cardboard boxes. A few require purchases from local or national suppliers.

Each project is introduced as a question: How much warmer do objects get in the sun than in the shade? What is the best color to paint a house to keep it cool in the summer? Which stores solar energy better—water or rock?

At the outset of an experiment, try to get your students to predict outcomes, even when they have no experience to justify their projections. Urge them to make a guess. They'll become more interested, feel more involved, if they do.

In order to answer each question, a student (or the class) follows instructions on an activity sheet that lead him or her through a specific experiment.

This kind of direct student participation leads easily to other related questions—some suggested on the activity sheets themselves, others generated by the students and their teacher—and to further exploration by the experimenters on their own.

The American Museum of Science & Energy has purposely used metric measurements throughout the experiments wherever practical, believing that this would be part of the learning process for many young people and for some adults as well.

Because the activities are outlined on a single sheets, you can easily photocopy them for distribution or project them on a screen or wall.

As the developers of the series, we are anxious to learn how you and your students use the materials, what variations you develop, and any results you find extraordinary. Please let us know your reactions to the materials, and feel free to ask for more information on any energy-related topic.

WIND ENERGY

Mankind has been making use of wind power for centuries. One of the first known uses was to propel sailing ships. This was followed, centuries later, by the development of windmills. Windmills enabled the Netherlands to become one of the world's most industrialized nations by the 17th century. In the United States, windmills played an increasingly important role in the nation's development from the early 1800's through the first quarter of the twentieth century. As use of fossil fuels became more widespread, the use of windmills became considerably less important in our economic development. Now, as we gradually use the world's known oil reserves, the use of wind power appears as an alternative source of energy to be harnessed for productive work.

Wind is a form of solar energy. About 2% of the solar radiation that falls on the earth is converted to wind energy in the atmosphere. At any given moment, half of the earth's atmosphere is exposed to the sun, and an equal amount is in shadow. The cyclical heating and cooling transforms the biosphere into a huge heat engine, generating energy, some of which is manifested as wind.

Like solar energy, the major drawback to the use of wind as an important energy source is the problem of storage. Wind can be used to generate electricity, but only if the winds constantly remain over 8-10 mph. Thus, effective storage mechanisms, such as batteries, must be used if wind is to be a substitute for current sources such as coal and oil. Like solar energy, wind is free and has potentially less harmful environmental impact than use of fossil fuels. Like solar energy, there are technological problems associated with storage.

The activities in this series cover some of the uses and problems associated with wind power.

This series, **Science Activities in Energy**, was developed by Oak Ridge Associated Universities under contract from the U.S. Department of Energy, with a staff under the direction of Mr. Mauri Gould. This publication was prepared as an account of work sponsored by the United States Government. Neither the United States nor the U.S. Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

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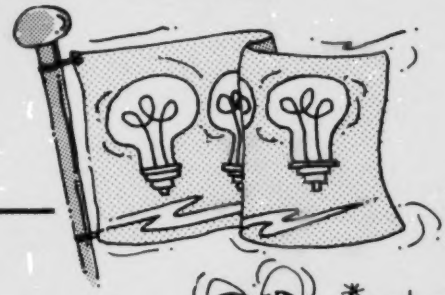
AT WHAT TIME OF DAY IS THERE ENOUGH WIND TO MAKE ELECTRICITY WHERE YOU LIVE?



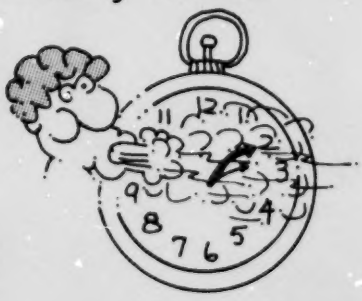
(no materials required)

Measure the wind with the Beaufort Wind Scale.

(Any wind over 5 mph can be used to generate electricity.)

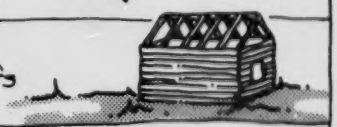
Keep a record of the wind speeds at different times of day.

At what time of day do the fastest winds usually occur?



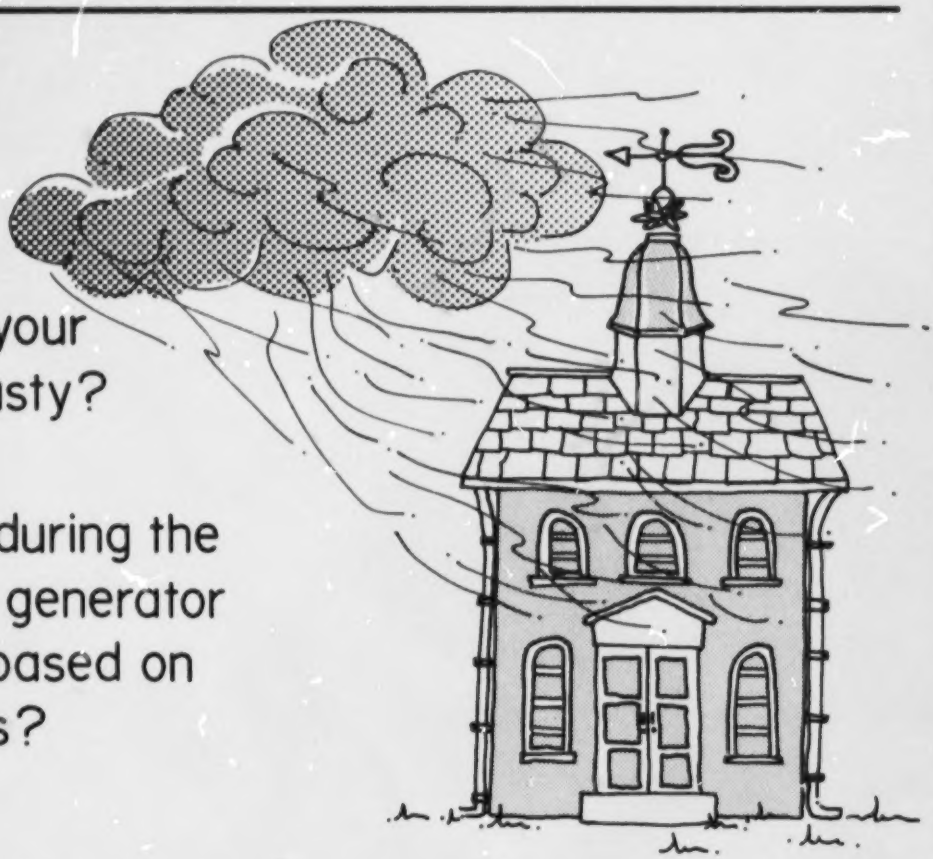
* mph = miles per hour

Beaufort number	Description*	Observation
0	calm (0-1 mph)	smoke rises vertically
1	light air (2-3 mph)	smoke drifts slowly
2	slight breeze (4-7 mph)	leaves rustle; windvane moves
3	gentle breeze (8-12 mph)	twigs move; flags extended
4	moderate breeze (13-18 mph)	branches move; dust and paper rise
5	fresh breeze (19-24 mph)	small trees sway
6	strong breeze (25-31 mph)	large branches sway; wires whistle
7	moderate gale (32-38 mph)	trees in motion; walking difficult
8	fresh gale (39-46 mph)	twigs break off trees
9	strong gale (47-54 mph)	branches break; roofs damaged
10	whole gale (55-63 mph)	trees snap; damage evident
11	storm (64-72 mph)	widespread damage
12	hurricane (73-82 mph)	extreme damage



KABOOM!

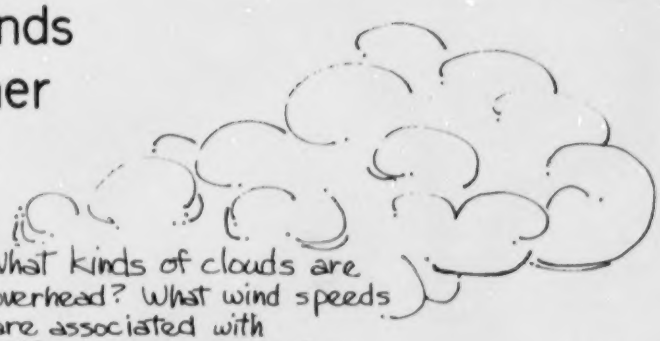
OTHER IDEAS TO EXPLORE:



Are the winds in your area steady or gusty?

How many hours during the day could a wind generator make electricity based on your observations?

Can you predict the winds from the clouds or other signs? How accurate are you?



What kinds of clouds are overhead? What wind speeds are associated with different types of clouds?

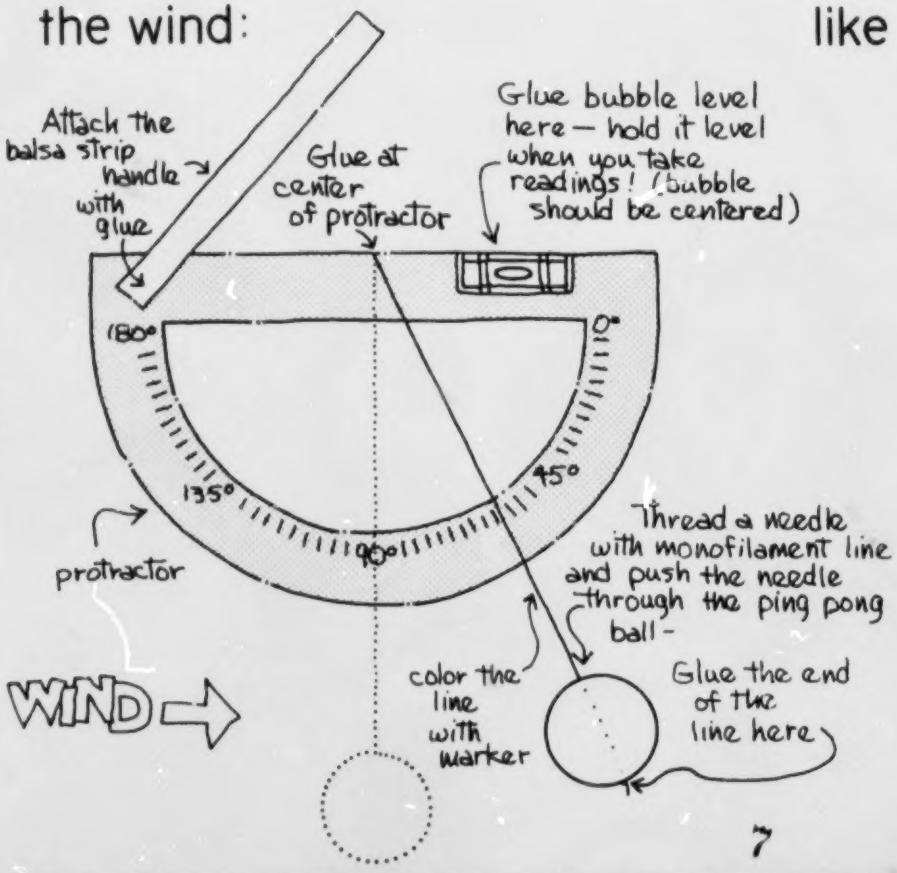
How accurate is the weather bureau in predicting the winds in your area?

WHERE IS THE WINDIEST SPOT ON YOUR SCHOOLGROUND?

MATERIALS:

1 ping pong ball
1 piece fishline (.08"-.02" diameter monofilament nylon line, 30 cm long – try a fishing/bait shop or sporting goods store)
Protractor; red magic marker
1 strip balsa, about 1/2cm square x about 18cm long (1/4" thick!)
1 bubble level (the kind with an air bubble inside – try a local hardware store)
Glue; needle (long enough to go through the ping pong ball)

Build a device to measure the wind:


Attach the balsa strip handle with glue
Glue at center of protractor
Glue bubble level here – hold it level when you take readings! (bubble should be centered)
180°
0°
135°
45°
90°
protractor
Thread a needle with monofilament line and push the needle through the ping pong ball
color the line with marker
Glue the end of the line here
WIND

Calibrate the wind speed like this:

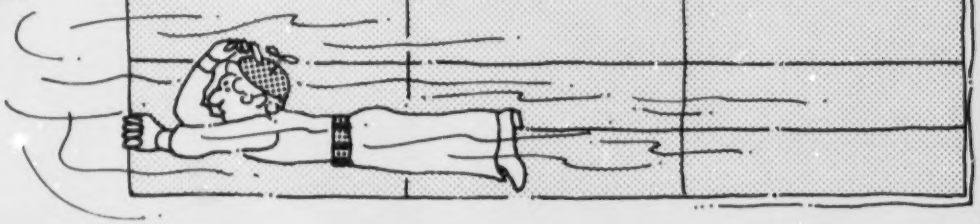
angle	mph*
90	0
85	5.8
80	8.2
75	10.1
70	11.8
65	13.4
60	14.9
55	16.4
50	18.0
45	19.6
40	21.4
35	23.4
30	25.8
25	28.7
20	32.5

*miles per hour

Test the wind at various places on your schoolground.

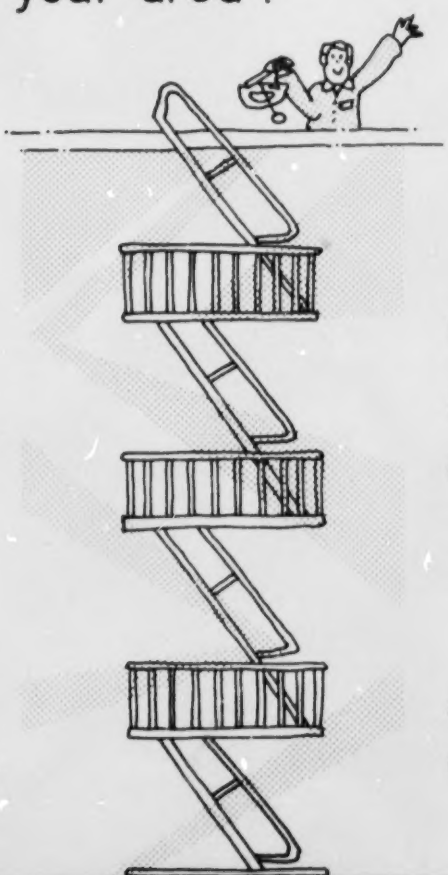
Keep a chart of your results!

LOCATION	WIND SPEED	TIME OF DAY



OTHER IDEAS TO EXPLORE:

Is there a strong wind between 2 buildings in your area?



What is the difference in wind speed at ground levels and at higher elevations?

↖ Try roofs of buildings that are easily accessible - and safe! (Talk to your Teacher about this)

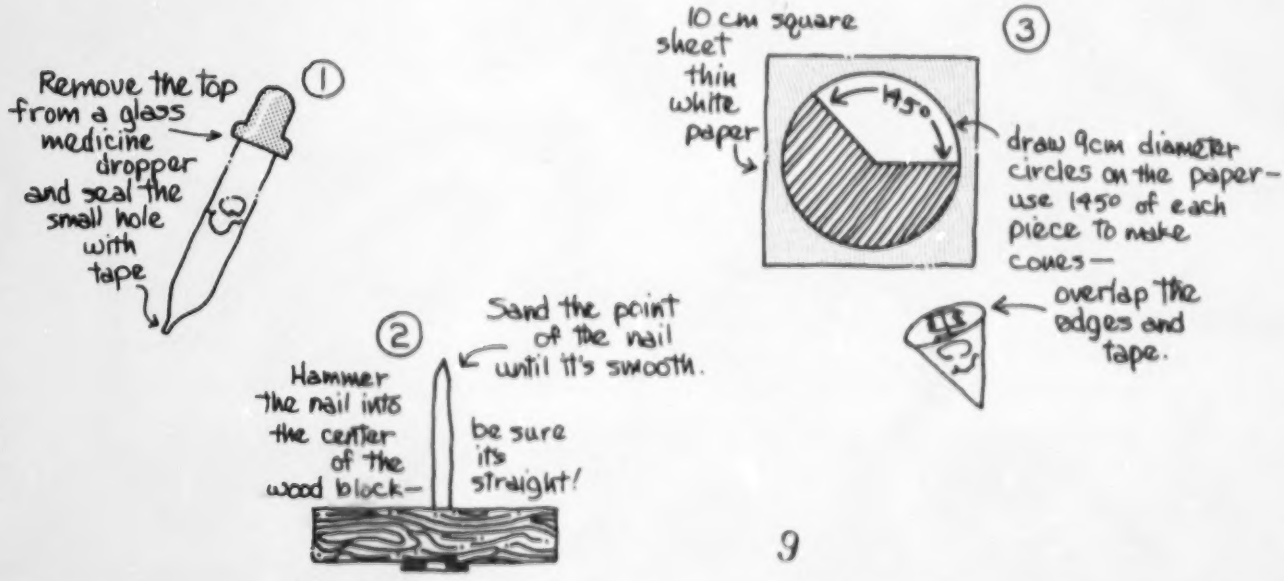
Are the winds stronger in the valley or in the hills where you live?

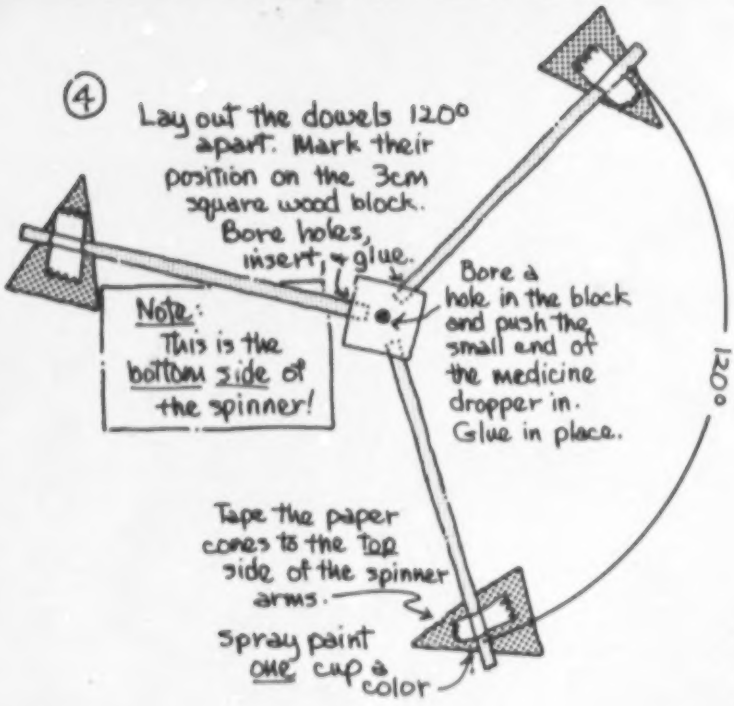
WHAT'S THE FASTEST WIND MEASURED ON YOUR SCHOOLGROUND DURING THE WEEK?

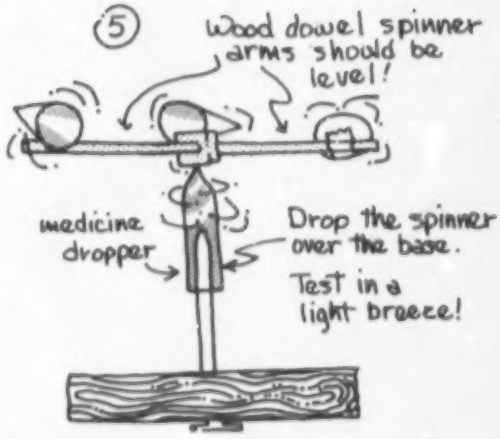
MATERIALS:

3 pieces wood dowel, 3/16" diameter x 15cm long
1 wood block, about 12cm square x 3/4" thick
1 16-penny nail; hammer; sandpaper
Glass medicine dropper
1 balsa block, 3cm square x 1/2" thick
3 sheets thin white paper, 10cm square
Glue; tape; protractor
Teacher's discretion! Hobby knife or pocket knife ← narrow blade!
Scissors; spray paint, any color ← red, blue, or black is best!

Build an anemometer ← a device used to measure wind speed! like this:


Remove the top from a glass medicine dropper and seal the small hole with tape
①
Hammer the nail into the center of the wood block—
②
Sand the point of the nail until it's smooth.
be sure it's straight!
10 cm square sheet thin white paper
③
145°
draw 9cm diameter circles on the paper— use 145° of each piece to make cones—
overlap the edges and tape.


④
Lay out the dowels 120° apart. Mark their position on the 3cm square wood block. Bore holes, insert, & glue.
Note: This is the bottom side of the spinner!
Bore a hole in the block and push the small end of the medicine dropper in. Glue in place.
120°
Tape the paper cones to the top side of the spinner arms.
Spray paint one cup a color



Mount the anemometer in an open area.

Record the wind speed at various places in your schoolyard for a week.

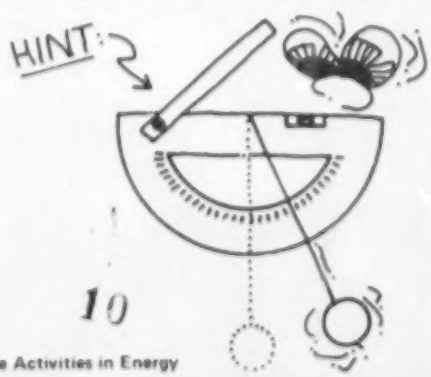
Compare results!

PLACE	M	T	W	Th	F

(Activity #1) Use the Beaufort Wind Scale to measure the wind speed!

OTHER IDEAS TO EXPLORE:

Can you calibrate your anemometer more accurately?



WILL A SAILBOAT GO ACROSS A LAKE FASTER WITH A CROSSWIND OR A TAILWIND?

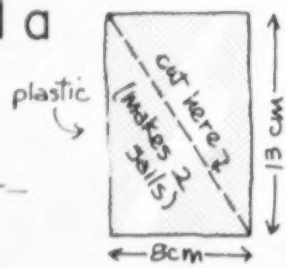
MATERIALS:

- 1 5cm x 10cm piece balsa (½" thick!)
- 1 4cm x 1cm strip aluminum (Use for rudder)
- 1 3/16" balsa dowel, 14.5cm long
- Hobby knife or single-edged razor blade (Teacher's discretion!)
- Masking tape; glue; scissors
- 8cm x 13cm piece plastic (Any kind will do – find something heavy enough to handle easily.)
- 1·1/2 meter square corrugated cardboard
- 1·1/2 meter square 3· or 4·mil plastic (Plastic trash bag may be large enough)
- Room fan; 1 4cm x 3cm strip aluminum
- Paper clips; 2 thumbtacks

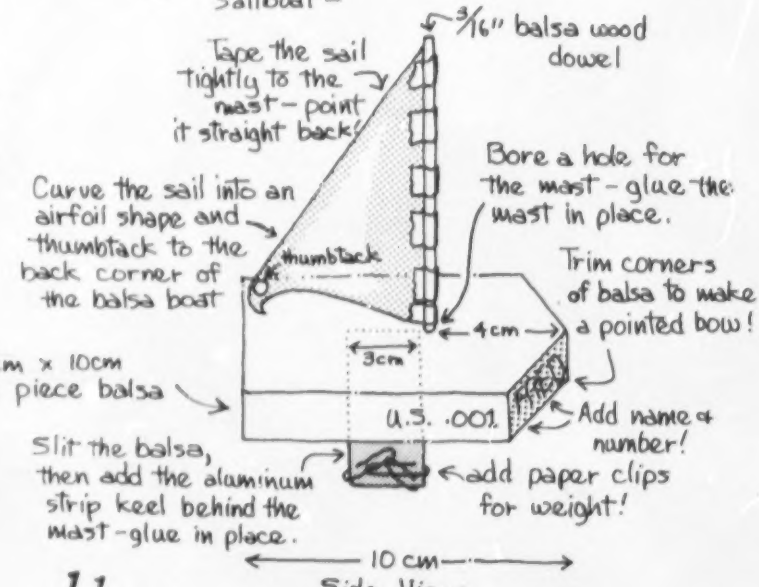
Note: Cut aluminum strips from disposable pie plates or frozen food containers.

First, build a sailboat:

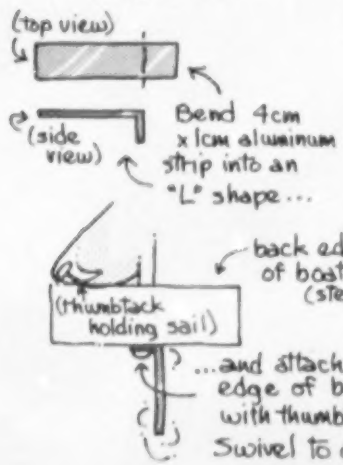
① Cut a sail –



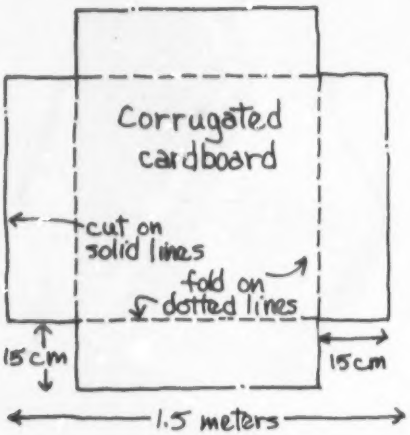
② Build the sailboat –

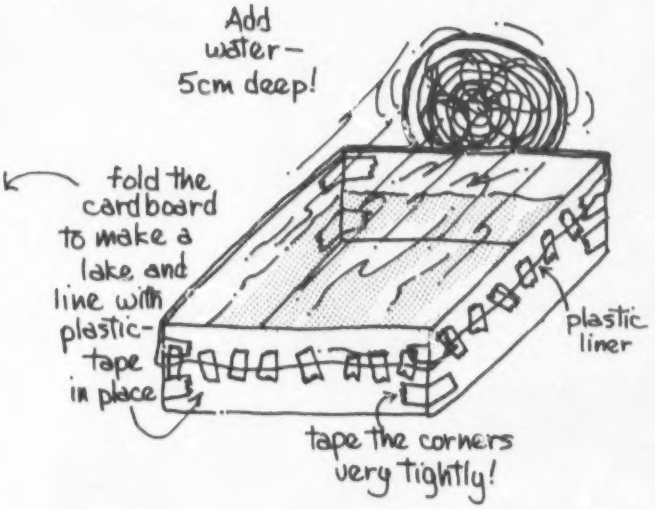

3/16" balsa wood dowel
Tape the sail tightly to the mast – point it straight back!
Bore a hole for the mast – glue the mast in place.
Curve the sail into an airfoil shape and thumbtack to the back corner of the balsa boat
thumbtack
Trim corners of balsa to make a pointed bow!
4cm
3cm
5cm x 10cm piece balsa
U.S. .001
Add name & number!
Slit the balsa, then add the aluminum strip keel behind the mast – glue in place.
add paper clips for weight!
10 cm
Side View

③ Add a rudder to your boat –

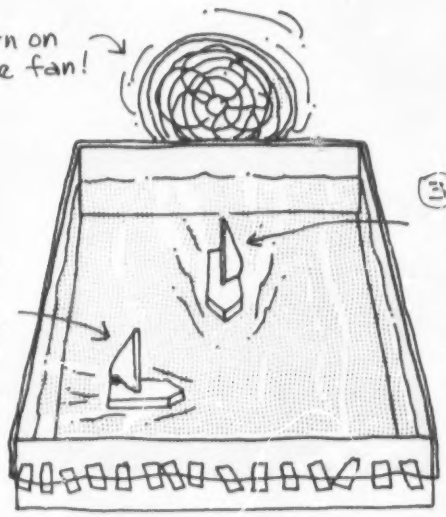

(top view)
(side view)
Bend 4cm x 1cm aluminum strip into an "L" shape...
back edge of boat (stern)
(thumbtack holding sail)
...and attach to edge of boat with thumbtack. Swivel to adjust.

Build a lake like this:




Add water – 5cm deep!
fold the cardboard to make a lake and line with plastic-tape in place
plastic liner
tape the corners very tightly!

Weigh anchor!



② Put the boat you made on the lake – adjust the rudder so that the boat crosses the lake.

Time how long it takes the boat to cross the lake.

_____
time with crosswind

③ Adjust the rudder so that the boat sails with the wind.

How long does it take the boat to go from one end of the lake to the other?

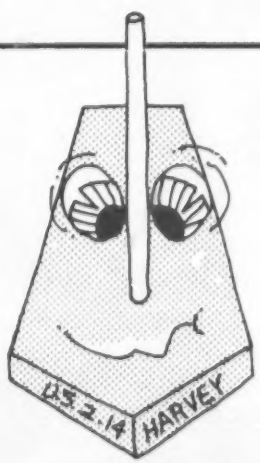
_____
time with tailwind

OTHER IDEAS TO EXPLORE:

What direction does the boat go with no keel?

What happens if the boat has no sail?

Can you make your sailboat sail against the wind?



WILL A SAILBOAT GO TWICE AS FAST IF THE SAIL IS TWICE AS LARGE?

MATERIALS:

Lake; fan; basic sailboat from Activity 4

1 5cm x 10cm piece balsa ← ½" thick!

1 4cm x 1cm strip aluminum ← Use for rudder

1 4cm x 3cm strip aluminum ← Use for keel

Paper clips; 2 thumbtacks; tape

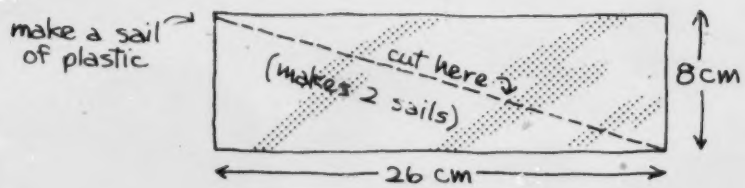
1 3/16" balsa dowel, 27.5cm long; scissors

8cm x 26cm piece plastic

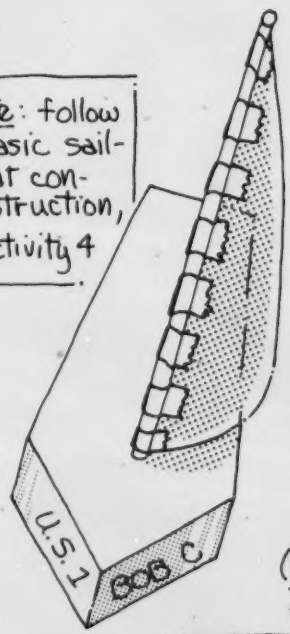
Teacher's discretion! Hobby knife or single-edged razor blade

Note: Cut aluminum strips from disposable pie plates or frozen food containers.

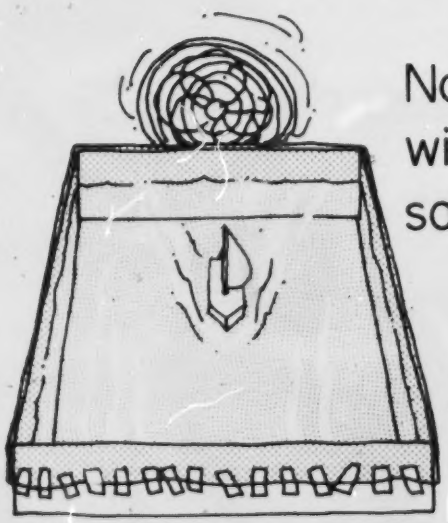
Make a second sailboat with a larger sail:



Note: follow basic sailboat construction, Activity 4



Now experiment with both sailboats:



Lake and fan from Activity 4

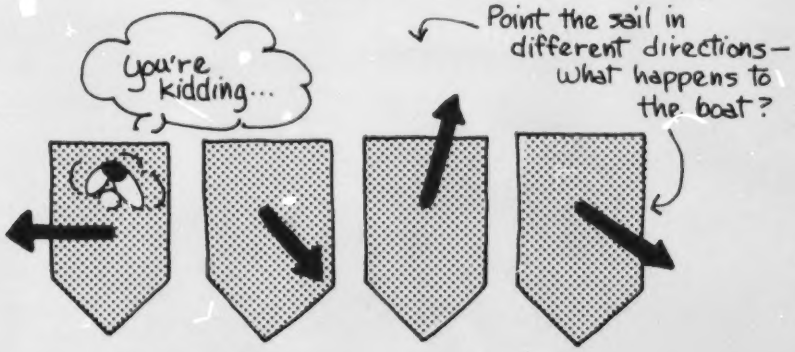
Time how long it takes each boat to cross the lake!

	Time
FRED	
BOB C	

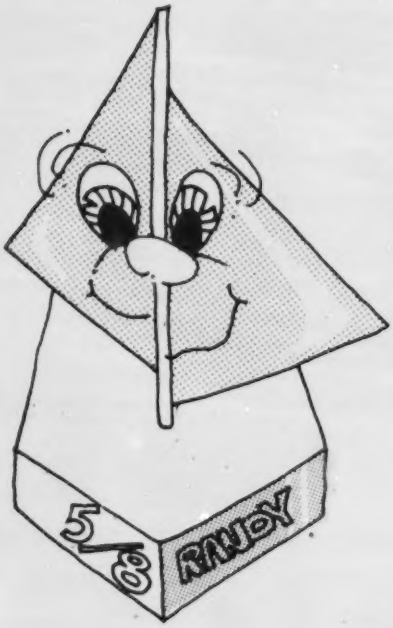
Does the large sail go faster?

OTHER IDEAS TO EXPLORE:

Try another

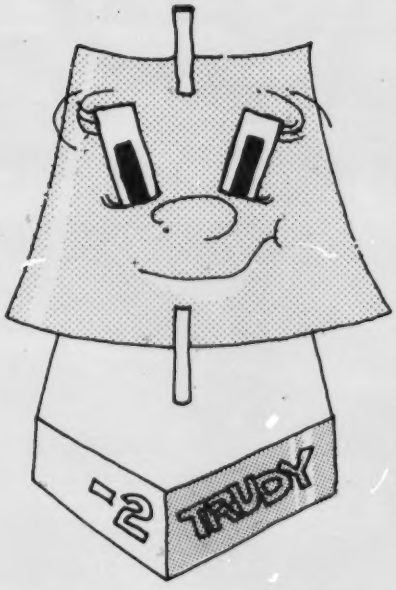


What direction does the boat travel away from the fan? Does it go faster or slower?



Put both sails on one boat!

Try using a square sail!



WHICH SHAPE OF BOAT WILL GO FASTEST?

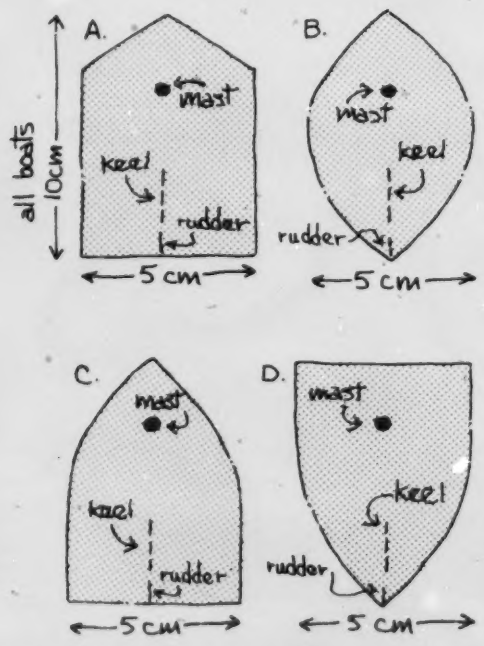
6

MATERIALS:

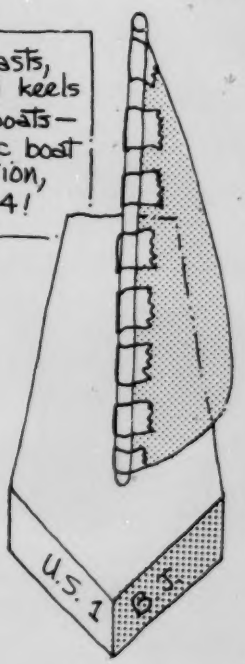
- 4 pieces 5cm x 1cm x 10cm balsa
- 4 strips 4cm x 1cm aluminum ← Use for rudder
- 4 strips 4cm x 3cm aluminum ← Use for keel
- Paper clips; 8 thumbtacks; tape
- 4 pieces 3/16" x 14.5cm long wood dowel
- 2 pieces plastic, 9cm x 12cm each ← each piece makes 2 sails!
- Scissors; glue; watch with second hand
- Teacher's discretion! → Hobby knife or single-edged razor blade
- Lake and fan from Activity 4

Note: Cut aluminum strips from disposable pie plates or frozen food containers.

Make 4 boats with these 4 basic shapes:

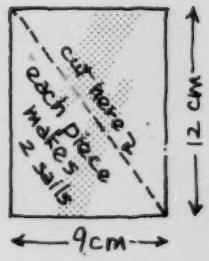


Add masts, sails, and keels to all 4 boats — see basic boat construction, Activity 4!

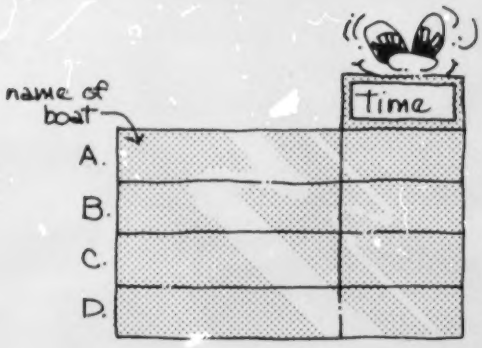


Put the boats together:

Cut 2 sheets of plastic to make 4 sails

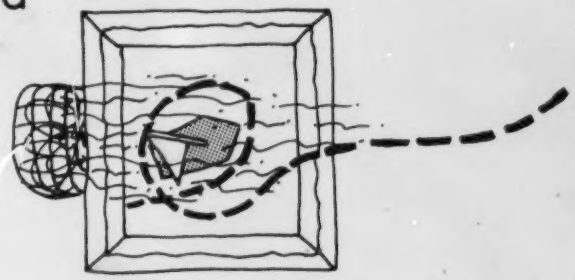


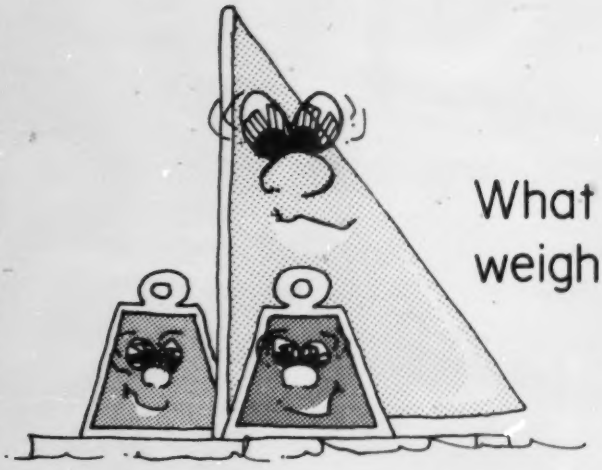
Which boat goes fastest ?



OTHER IDEAS TO EXPLORE:

Can you design a faster boat ?





What happens when you add weight to the boat ?

THE GREAT SAILBOAT · RACE

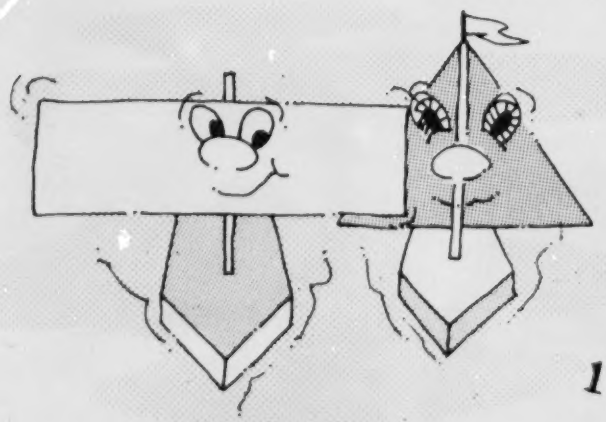
7

MATERIALS:

- Sailboats for each student ← See Activities 4, 5, & 6 for sailboat construction.
- Body of water ← A local lake or pond
- Breezy day ← Pick a good one!

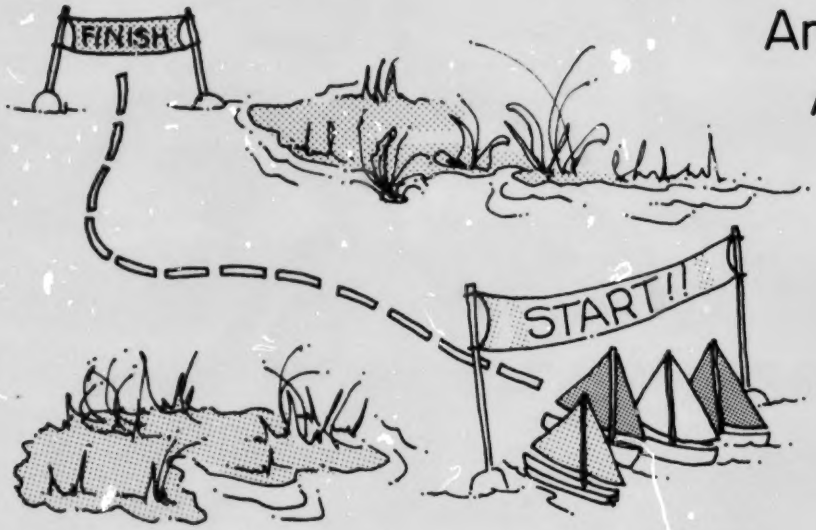
The class may wish to set regulations for the race: ← Set as many or as few regulations as you wish!

- Maximum weight and dimensions of boats.
- Size and number of sails.
- Distance and course to be sailed.



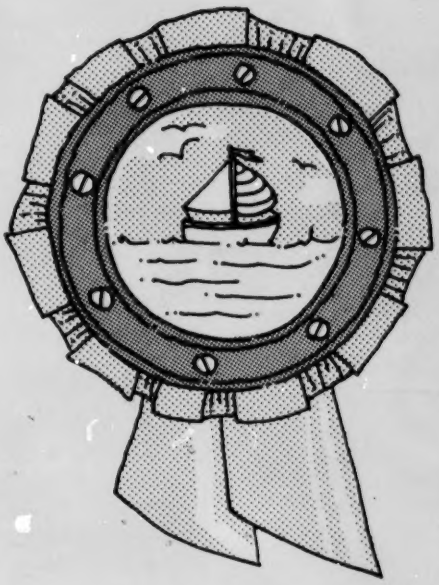
Teacher's Discretion!

Each student should build a sailboat.

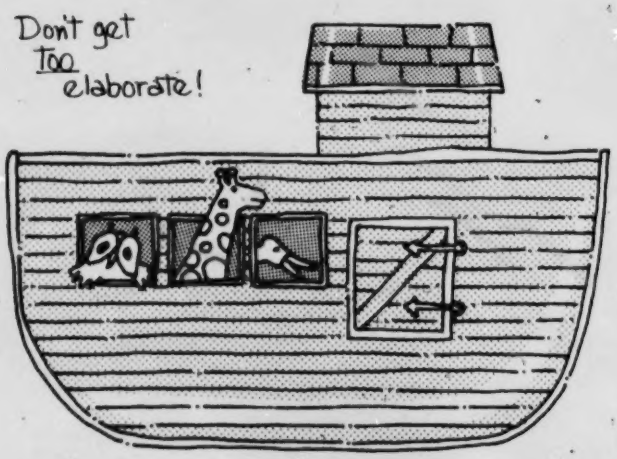


Anchors Aweigh!

Award a badge to the winning captain!



OTHER IDEAS TO EXPLORE:



Build models of different types of boats.

Compare their advantages and disadvantages!

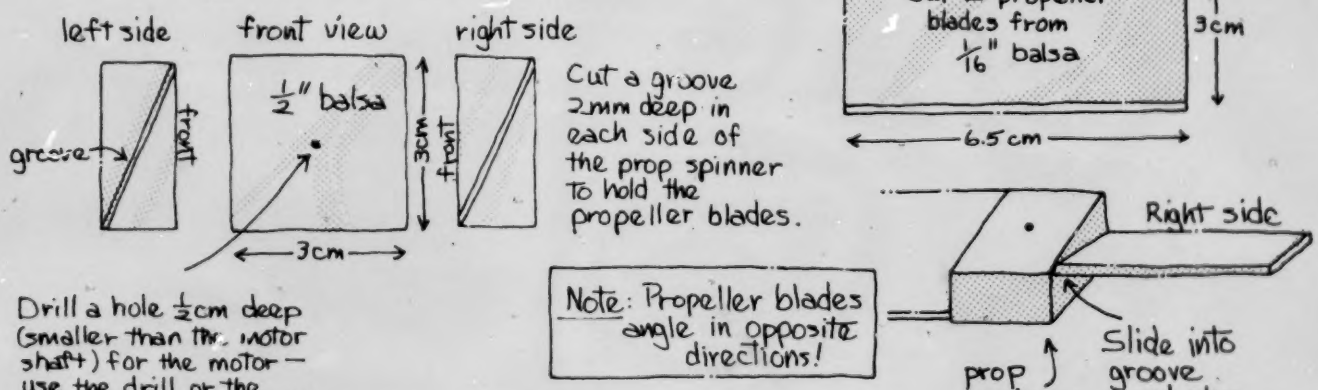
WHAT IS THE BEST ANGLE AT WHICH TO SET THE BLADES OF A PROPELLER TO MAKE ELECTRICITY?

MATERIALS:

- Balsa wood, 1/16" thick piece ← Use for making all propellers in Activities 8 and 9
- Balsa wood, 1/2" thick piece
- Small 1 1/2 volt DC motor ← (available from the American Museum of Science & Energy – about 50¢)
- Voltmeter, 0-5 volts
- 100 ohm, 1/2-watt resistor ← (try a local electronics hobby shop)
- Powerful 2-or 3-speed room fan ← (different fans give different results – experiment with more than one)
- Fine hacksaw blade, glue
- Single-edged razor blade [Teacher's discretion!]
- Small nail and hammer or drill
- Plastic insulated hookup wire, about 30cm
- Plastic model airplane propeller

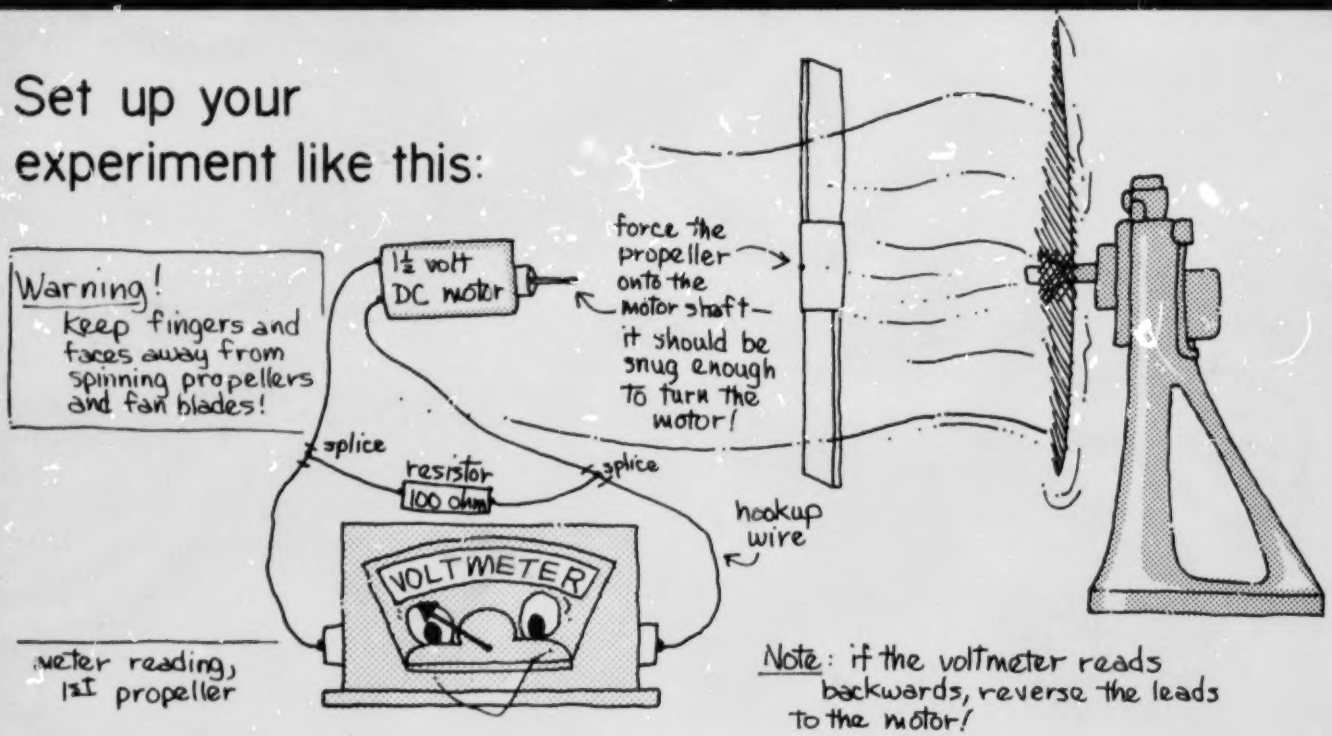
Note: The balsa propellers you make below do not have an airfoil shape – the model airplane propeller does.

Build a propeller like this:


left side
front view
right side
groove
front
1/2" balsa
3cm
front
3cm
Drill a hole 1/2cm deep (smaller than the motor shaft) for the motor – use the drill or the hammer and small nail.
Cut a groove 2mm deep in each side of the prop spinner to hold the propeller blades.
Cut 2 propeller blades from 1/16" balsa
3cm
6.5cm
Right side
Note: Propeller blades angle in opposite directions!
prop spinner
Slide into groove and glue
Left side

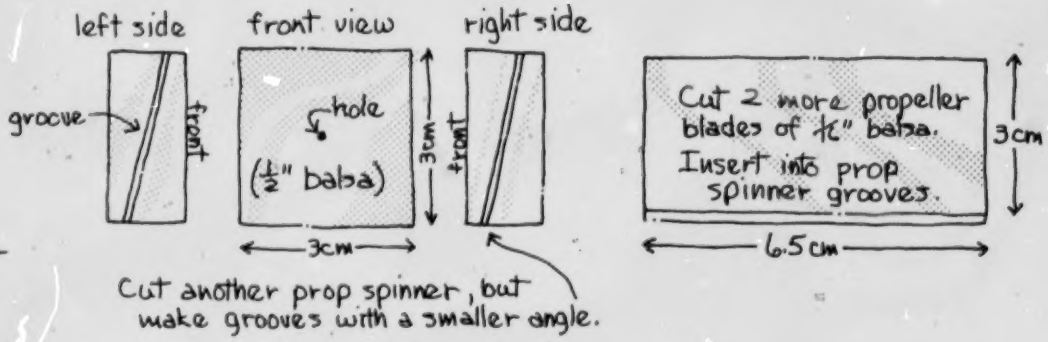
Put the pieces together like this:

Set up your experiment like this:


Warning!
Keep fingers and faces away from spinning propellers and fan blades!
1½ volt DC motor
force the propeller onto the motor shaft— it should be snug enough to turn the motor!
splice
resistor 100 ohm
splice
hookup wire
VOLTMETER
meter reading, 1st propeller

Note: if the voltmeter reads backwards, reverse the leads to the motor!

Now, build a second propeller; test it like the first.

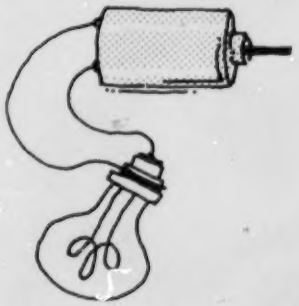


Which angle produced more electricity?

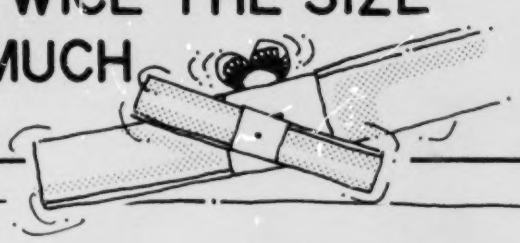
OTHER IDEAS TO EXPLORE:

How much electricity will be produced if the wind speed is cut in half?

Can make you enough electricity to light a single flashlight lamp?



WILL A PROPELLER TWICE THE SIZE PRODUCE TWICE AS MUCH ELECTRICITY?



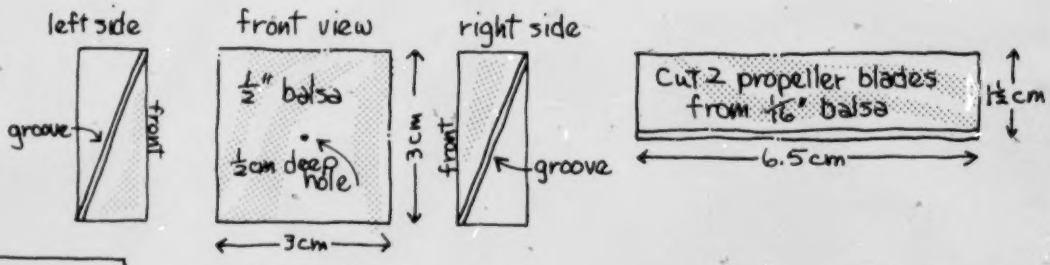
MATERIALS:

- Balsa wood from Activity 8
- Powerful 2· or 3· speed room fan (different fans give different results – experiment with more than one)
- Teacher's Discretion! Fine hacksaw blade; single-edged razor blade
- Small nail and hammer or drill; glue
- *Small 1 1/2 volt DC motor (available from the American Museum of Science & Energy – about 50¢)
- *Voltmeter, 0-5 volts
- *100 ohm, 1/2 watt resistor (Try a local electronics hobby shop)
- *Plastic insulated hookup wire, about 30cm
- *Basic propeller from Activity 8
- Plastic model airplane propeller

*Note: if you have completed Activity 8, these materials are already assembled!

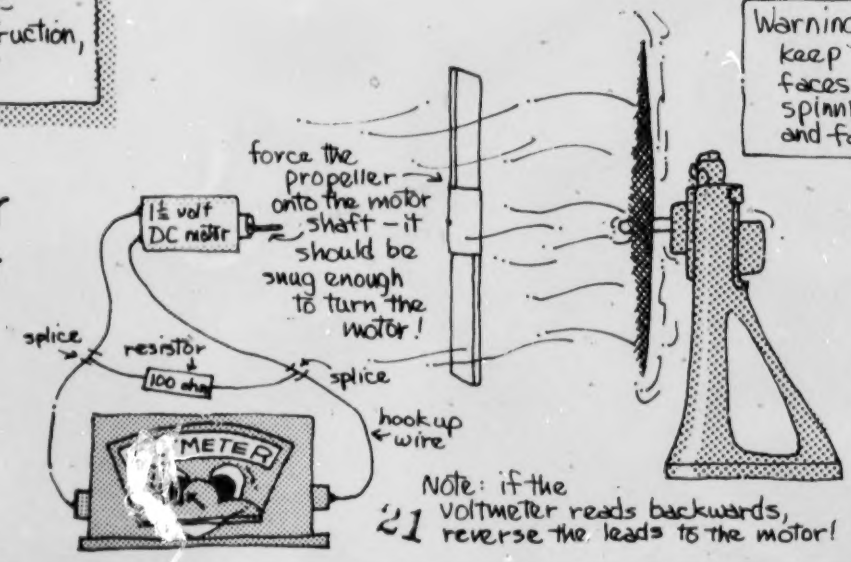
Note: The balsa propellers you make below do not have an airfoil shape – the model airplane propeller does.

Build this propeller version:



Note: follow basic propeller construction, Activity 8.

Set up your experiment like this:



Warning! keep fingers and faces away from spinning propellers and fan blades!

Note: if the voltmeter reads backwards, reverse the leads to the motor!

OTHER IDEAS TO EXPLORE:

Calculate and compare the electric power produced:

Example:
Meter reading — .6 volts
$\frac{.6 \times .6}{100} = .0036$ watts

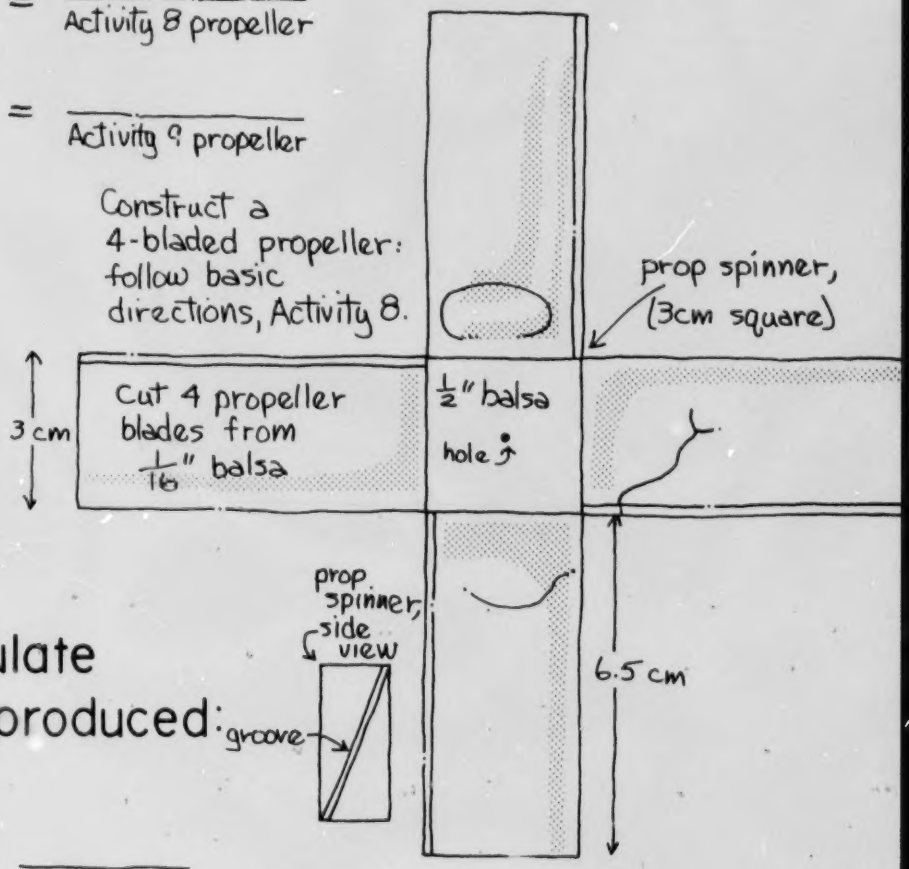
$$\text{POWER} = \frac{\text{VOLTAGE} \times \text{VOLTAGE}}{100}$$

= Activity 8 propeller

= Activity ? propeller

Will a 4-bladed propeller produce more electricity than a 2-bladed propeller?

Construct a 4-bladed propeller: follow basic directions, Activity 8.

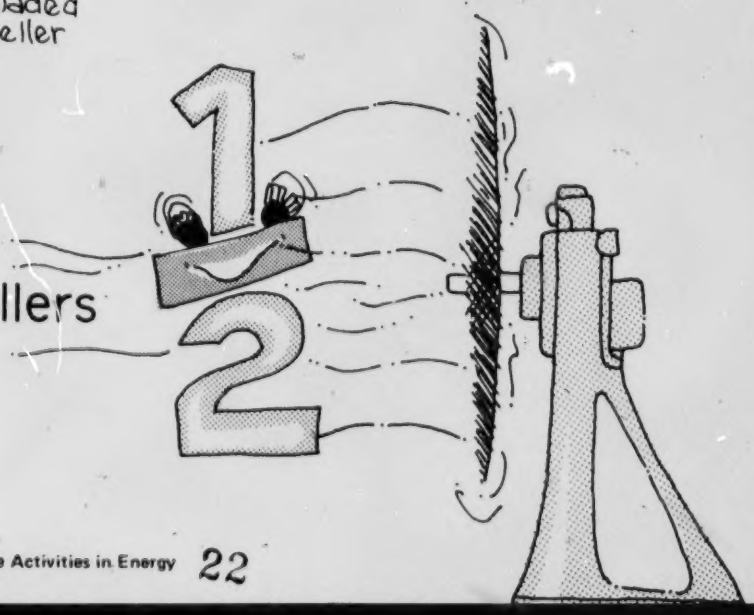


Test this propeller as above, and calculate the electric power produced:

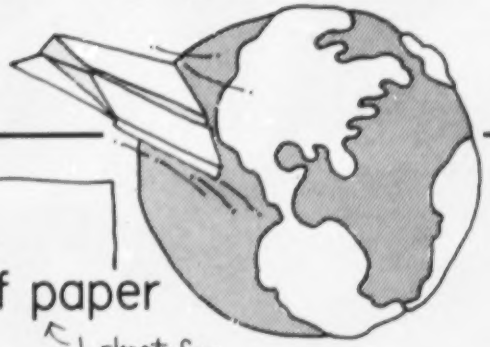
$$\text{POWER} = \frac{\text{VOLTAGE} \times \text{VOLTAGE}}{100} = \text{4-bladed propeller}$$

Compare the results of all propellers.

How would your propellers work if you cut the wind speed in half?



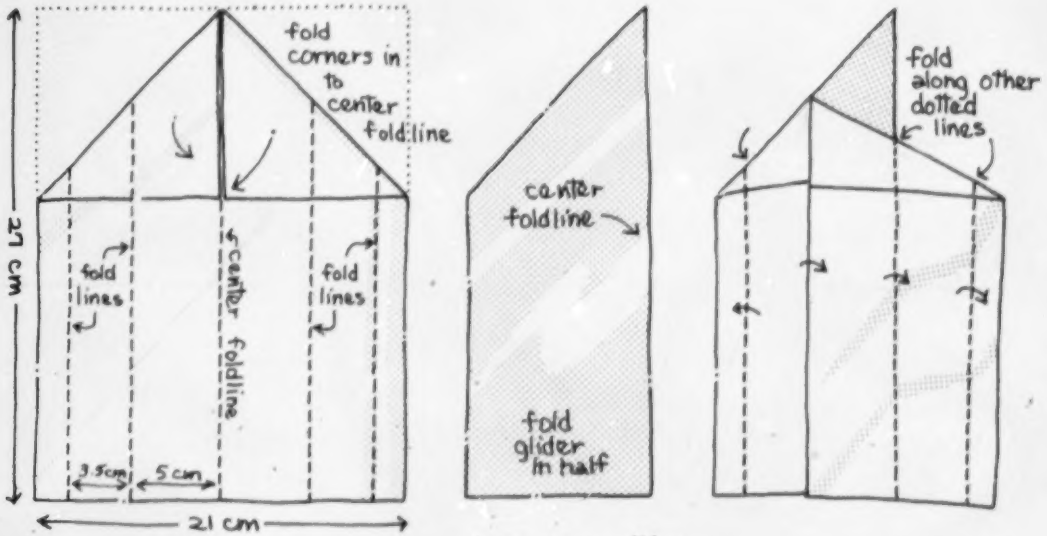
WHAT'S THE GREATEST DISTANCE YOU CAN MAKE A PAPER GLIDER FLY?



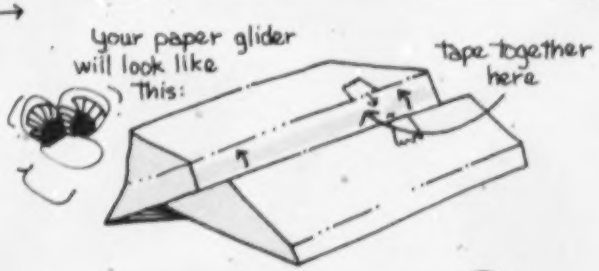
MATERIALS:

21cm x 27cm sheets of paper (1 sheet for each student)
Scissors; paper clips
2-sided adhesive tape

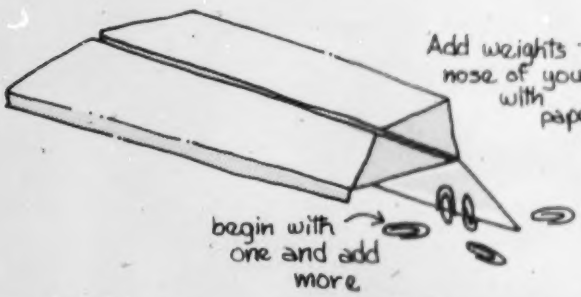
Construct a paper glider:

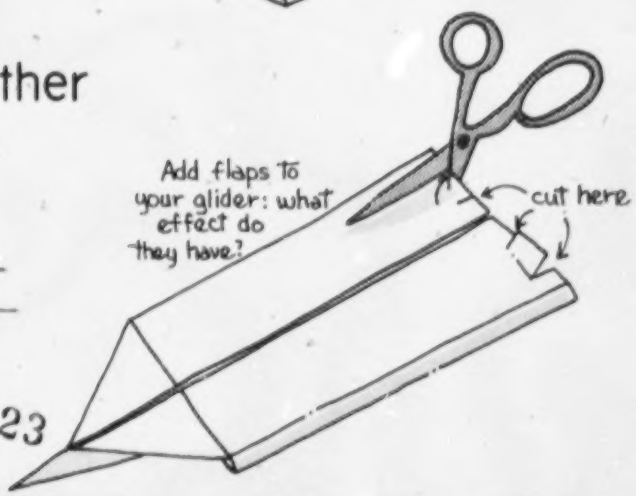


How far will your paper glider fly?



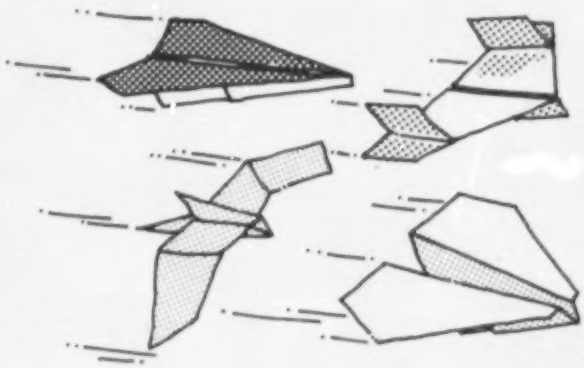
Will your airplane travel farther with these variations?





OTHER IDEAS TO EXPLORE:

Have a paper glider race!



Try different combinations of weights (paper clips) and flaps.

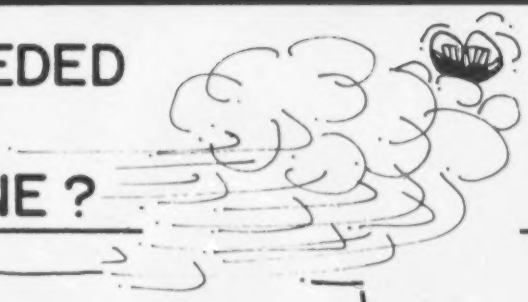
Different types of paper and different wingspans are other variations to experiment with.

Do the height from which the glider is thrown and the launching speed affect the distance the glider travels?

Decorations of various types can affect the performance, too!

Award the winners of your contest Junior Birdman badges!

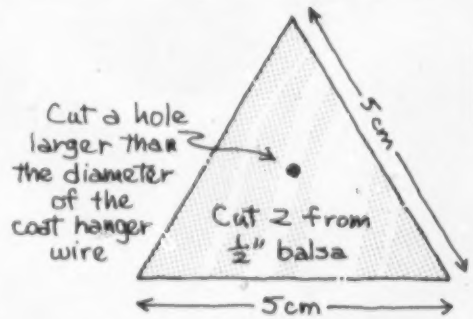
HOW MUCH WIND IS NEEDED TO TURN A MODERN WIND MACHINE ?

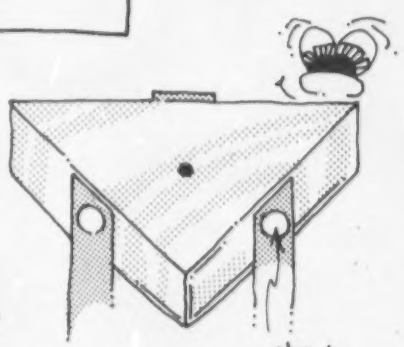


MATERIALS:

1 balsa wood dowel, 3/16" x 35.5cm
2 coat hangers; 6 thumbtacks
3 pieces construction paper, 35.5cm x 1.25cm
3 corks; drill; glue; 4 wooden spools ← ask anyone who sews!
1 piece 1/2" balsa, 5cm x 10cm
1 empty 1 lb. salt box; tape
Teacher's discretion! Hobby knife; 1 sheet balsa, 1/6" thick
Magic marker, any color

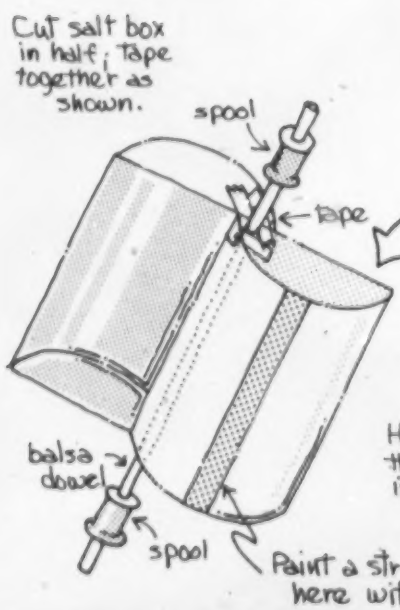
Make these 3 modern wind machines.





attach the 3 paper strips with thumbtacks

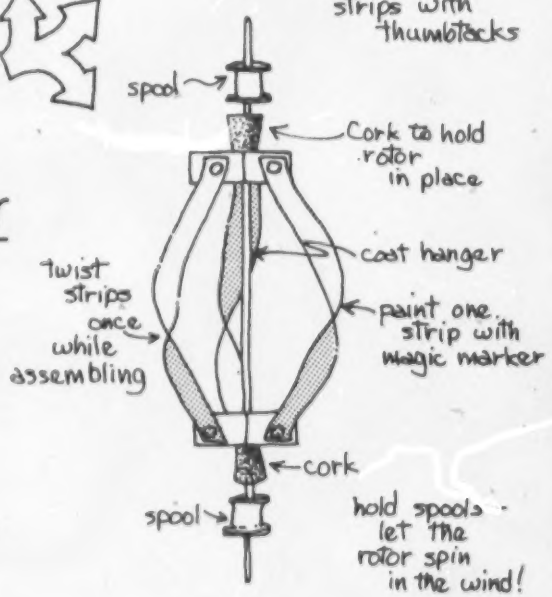
Helix Rotor



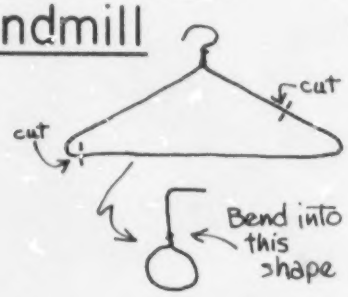
Savonius Rotor

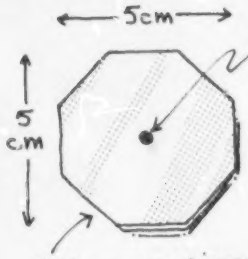
Punch holes and insert balsa dowel.

Hold spools – let the rotor spin in the wind!


spool
Cork to hold rotor in place
coat hanger
twist strips once while assembling
paint one strip with magic marker
cork
spool
hold spools - let the rotor spin in the wind!

Conventional Windmill

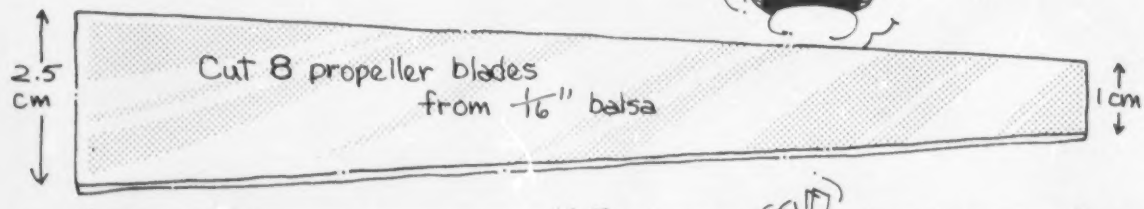


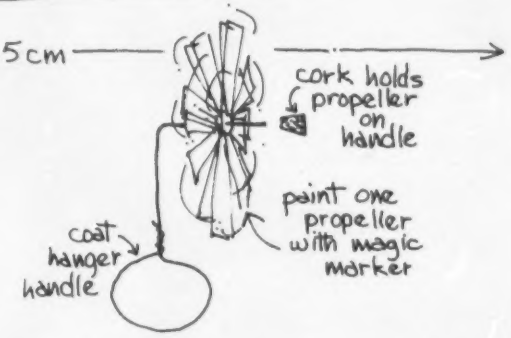


drill a hole in the center slightly larger than the diameter of the coat hanger wire

Cut a prop spinner from $\frac{1}{2}$" balsa

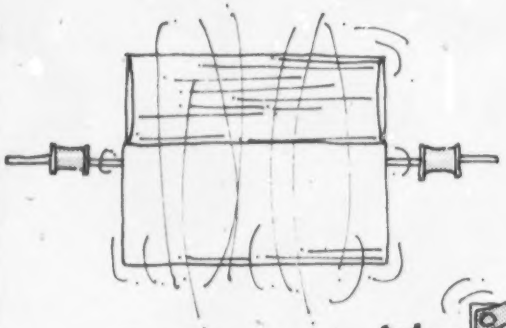
Cut grooves in all edges with a hobby knife – insert propeller blades and glue.





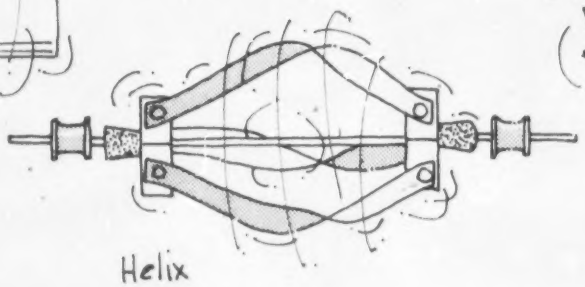
Face each of the wind machines into the wind. Using the wind measuring device from Activity 3, calibrate the wind speed.

Count the number of times each turns in a given amount of time – watch for the stripe of color!



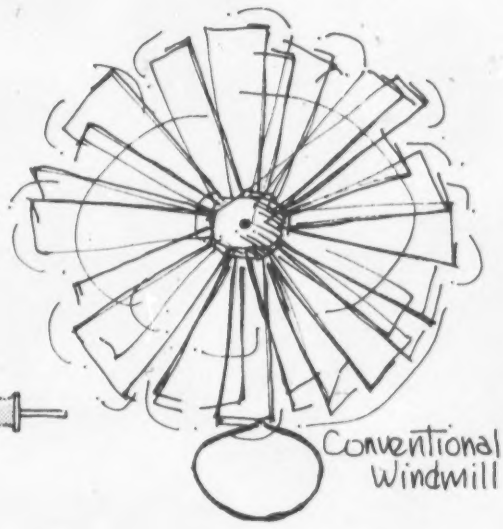
Savonius Rotor

_____
number of Turns



Helix Rotor

_____
number of Turns

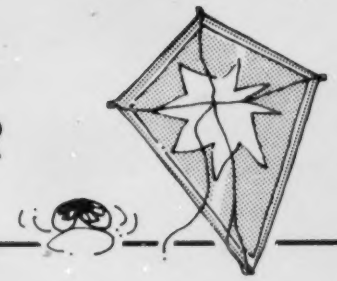


Conventional Windmill

_____
number of Turns

Which wind machine turns with the least wind?

WHICH KITE WILL FLY HIGHER, A SMALL ONE OR ONE TWICE AS LARGE?



1/4" square balsa sticks in the following lengths:

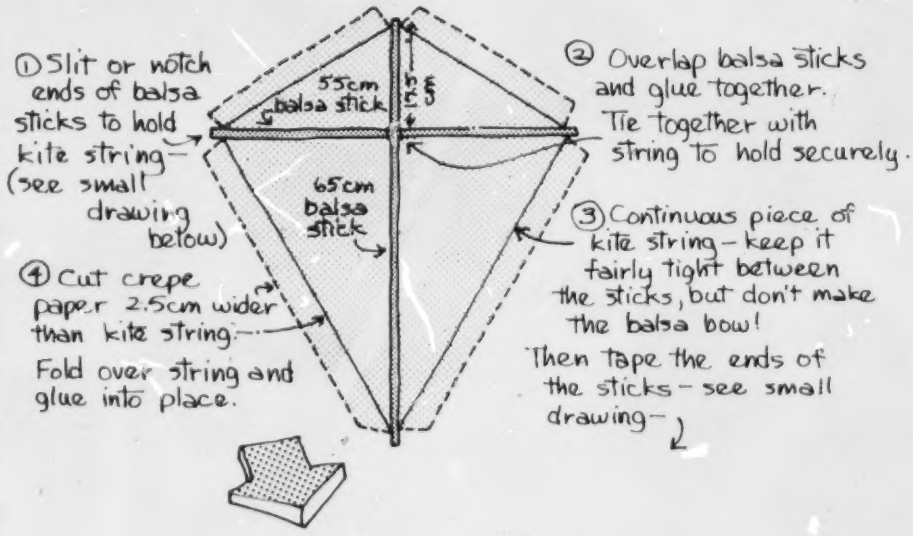
1 65cm long	1 27.5cm long
Enough for 2 kites! 1 55cm long	1 32.5cm long

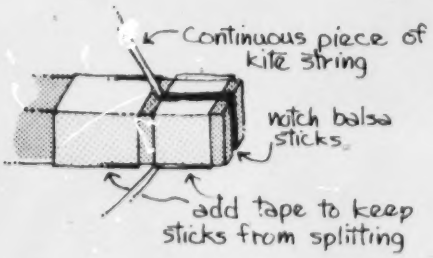
Crepe paper; 2 large rubber bands

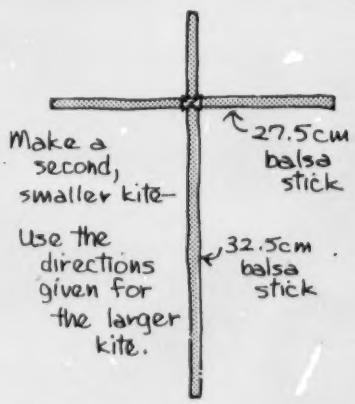
2 rolls kite string; scissors

White glue; masking tape

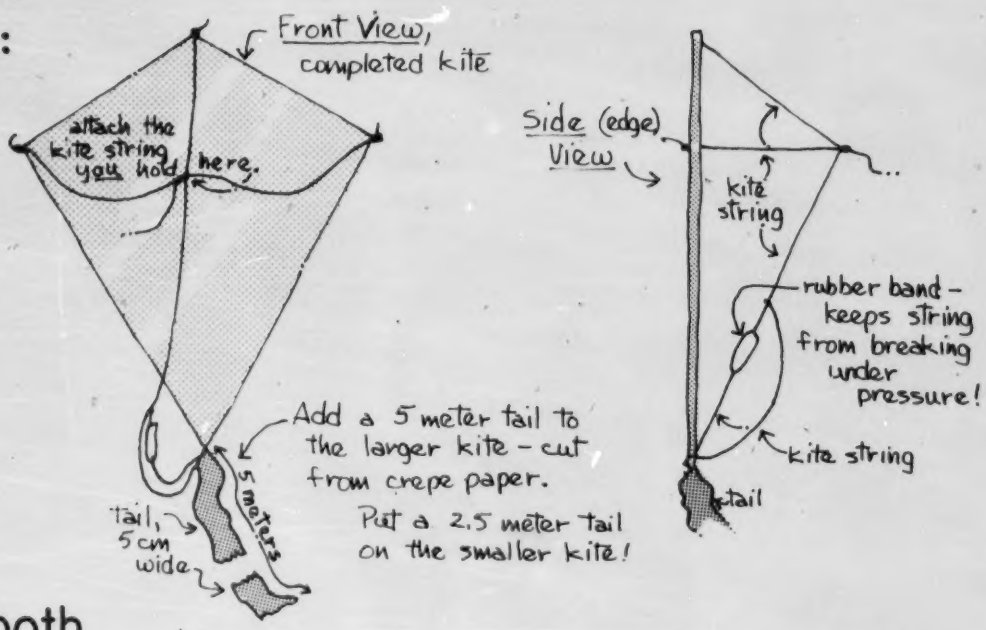
First, build 2 kites:


① Slit or notch ends of balsa sticks to hold kite string— (see small drawing below)
55cm balsa stick
32.5cm
65cm balsa stick
② Overlap balsa sticks and glue together. Tie together with string to hold securely.
③ Continuous piece of kite string— keep it fairly tight between the sticks, but don't make the balsa bow! Then tape the ends of the sticks — see small drawing—
④ Cut crepe paper 2.5cm wider than kite string— Fold over string and glue into place.





Add bridles and tails to both kites:


Front View, completed kite
attach the kite string you hold here.
Add a 5 meter tail to the larger kite - cut from crepe paper.
Put a 2.5 meter tail on the smaller kite!
tail, 5 cm wide
5 meters
Side (edge) View
kite string
rubber band - keeps string from breaking under pressure!
kite string
tail

Now, fly both kites. Which one flies higher?

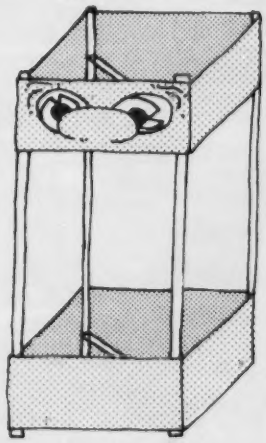
OTHER IDEAS TO EXPLORE:

What is the least amount of wind needed to fly a kite?

Will a kite fly without a tail?

Would a box kite fly higher than the one you made?

Have a kite-flying contest!



Activities in this Series include:

1. AT WHAT TIME OF DAY IS THERE ENOUGH WIND TO MAKE ELECTRICITY WHERE YOU LIVE?
2. WHERE IS THE WINDIEST SPOT ON YOUR SCHOOLGROUND?
3. WHAT'S THE FASTEST WIND MEASURED ON YOUR SCHOOLGROUND DURING THE WEEK?
4. WILL A SAILBOAT GO ACROSS A LAKE FASTER WITH A CROSSWIND OR A TAILWIND?
5. WILL A SAILBOAT GO TWICE AS FAST IF THE SAIL IS TWICE AS LARGE?
6. WHICH SHAPE OF BOAT WILL GO FASTEST?
7. THE GREAT SAILBOAT RACE
8. WHAT IS THE BEST ANGLE AT WHICH TO SET THE BLADES OF A PROPELLER TO MAKE ELECTRICITY?
9. WILL A PROPELLER TWICE THE SIZE PRODUCE TWICE AS MUCH ELECTRICITY?
10. WHAT'S THE GREATEST DISTANCE YOU CAN MAKE A PAPER GLIDER FLY?
11. HOW MUCH WIND IS NEEDED TO TURN A MODERN WIND MACHINE?
12. WHICH KITE WILL FLY HIGHER, A SMALL ONE OR ONE TWICE AS LARGE?